# Factor of Safety Lab Report

4/8/2026
Caleb Hottes

## 1. Design

The purpose of this lab is to experimentally determine the factor of safety of a OSHA certified tow strap. These straps are rated for 2000lbf in pure tension and 4000lbf in double tension with a claimed factor of safety of five. A piece of tooling was designed to facilitate a test to determine the real factor of safety for these straps. The constraints of this design were that it must fit in the jaws of the press, be under $150, be capable of breaking a strap in single tension, and be reusable.

**Design Description**

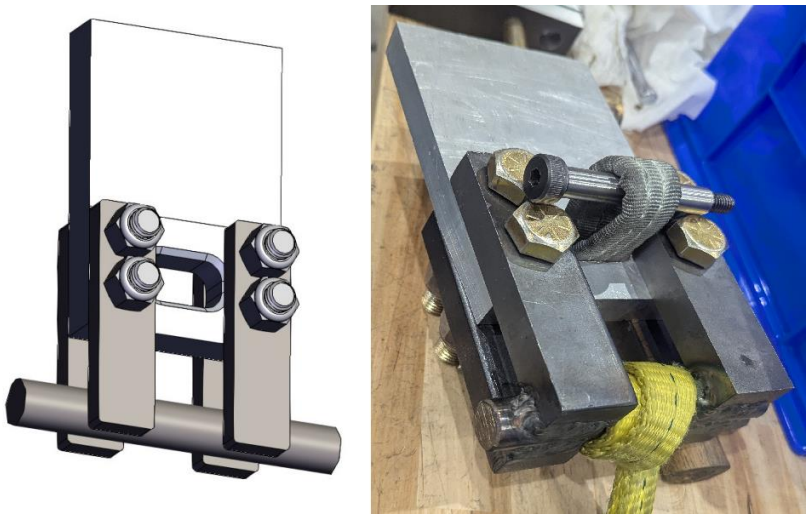

*Figure 1: Comparison of CAD design and real tooling*

As shown in figure 1, the design retains the strap by wrapping it around the cylinder, feeding the end through the hole and pinning the strap. By wrapping the strap around the bar, friction is leveraged to drastically reduce the load on the pin. The load is transferred from the strap to the round bar and then through the large steel bars to the bolts. The bolts are loaded in shear and connect to the aluminum plate with is gripped by the jaws of the press. The jaws are knurled and dig into the plate, creating a strong grip. Two materials were used because the lower hardness of aluminum allows the steel jaws of the press to more firmly grip the plate. The rest of the design is manufactured as five steel parts but welded together and bolted on to the aluminum plate.

**Analysis**

This analysis considers a load of 8000lbf applied by the strap. According to a chart available online the grade 8, 5/8th in bolts loaded in double shear on the shank can withstand 33,000lbf, which multiplied by four bolts is far beyond the expected loads. However I may be reading the chart incorrectly, the bolt may be loaded in single shear twice, which would result in a strength of 13000lbf, which is still far above the 2000lbf expected for each bolt. A quick FEA study revealed that for 2000lbf applied on the end of one of the steel bars with the bolt holes pinned, 65.8MPa of stress was developed resulting in a FoS of 5.3. (See figure 2) Overall the device is not expected to fail or deform when loaded with 8000lbf. The strap is expected to fail in tension at the spot where it wraps around the cylinder, given that at that point it is turning so it has some shear/bending in addition to the tension.

Overall the design should withstand loading the strap in single tension with a FoS of 5.3 and double tension with a FoS of 2.65.

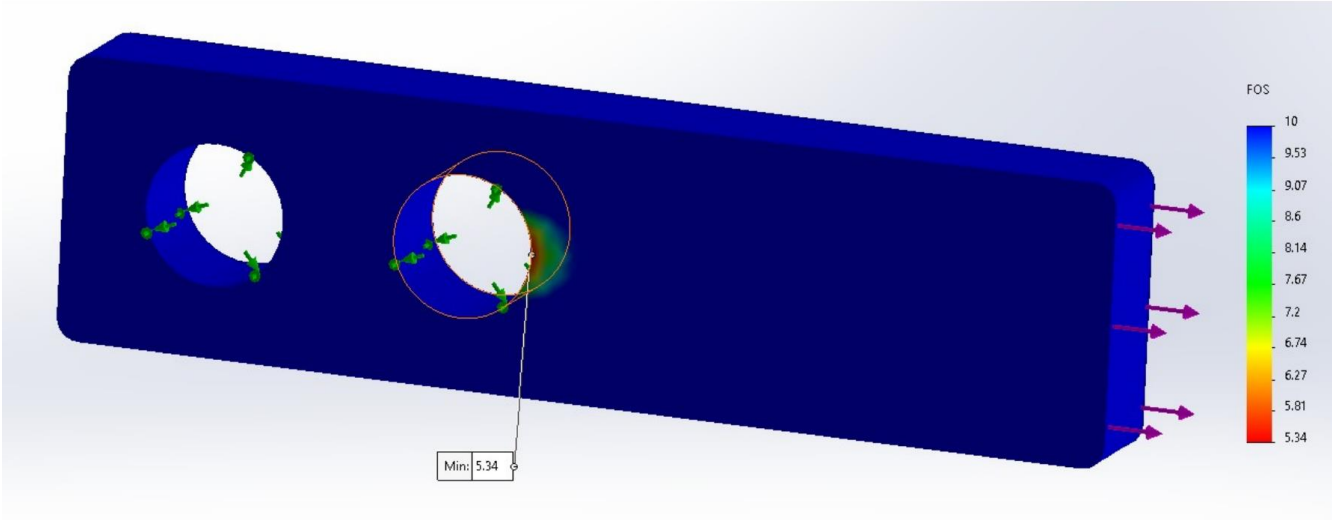


*Figure 2: Tensile analysis of the steel bars*

# 2. Experimental Results

The test setup was not as originally designed. The strap we had available to break was too long to fit in the press as designed, so we elected to test the strap doubled up, being loaded in double tension. This shortens the strap and doubles the breaking point. To do this, both ends of the strap were pinned on the bottom part of the press with on pin on each side of the tooling. This setup caused there to be a large mass of wrapped strap on the bottom piece of tooling. The test was split into two sessions because during the initial loading, the bottom tool came out of the jaws causing the setup to need to be reset.

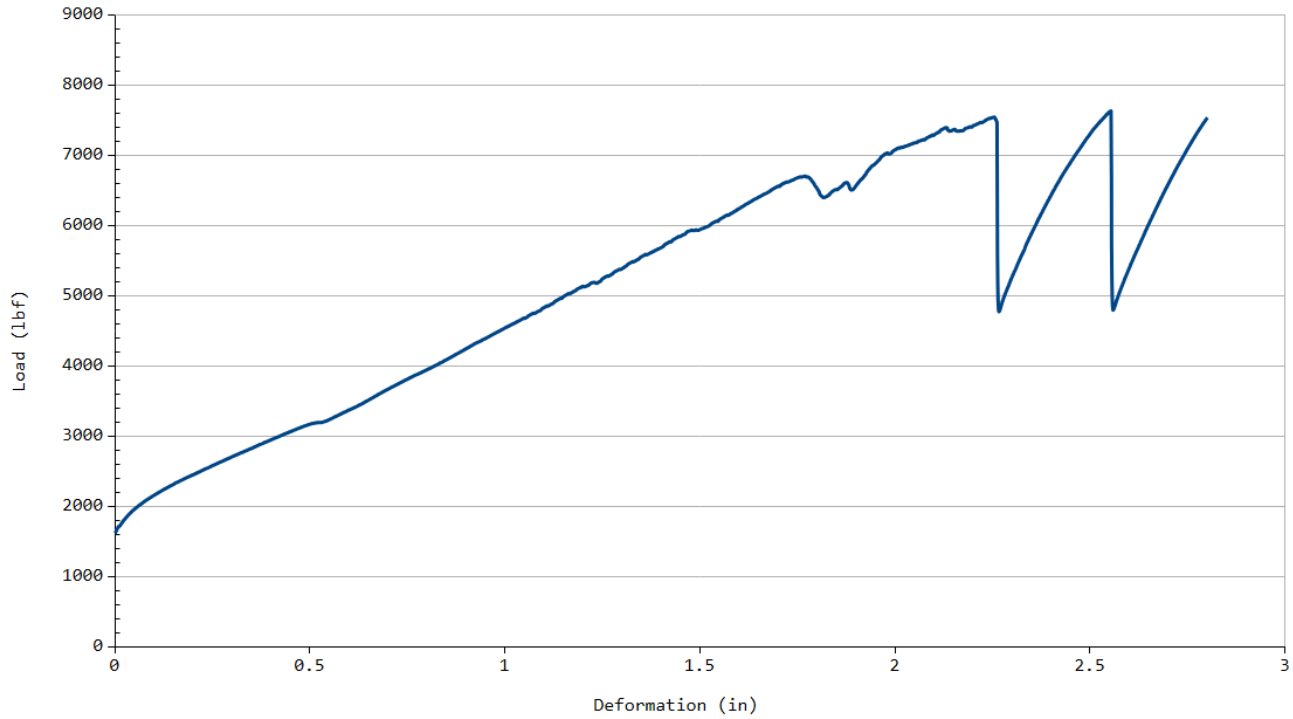


*Figure 3: Initial Test Results, test ends when tool slips out of jaws.*

During the initial test shown in figure 3, the peak force is 7634lbf with two large drops in force during the test. These drops are of magnitude 2694lbf and 2837lbf respectively.
After resetting the machine we conducted a second test, shown in figure 4, which ended in the failure of the strap. The force was applied linearly with no drops and the strap failed at 10717lbf.

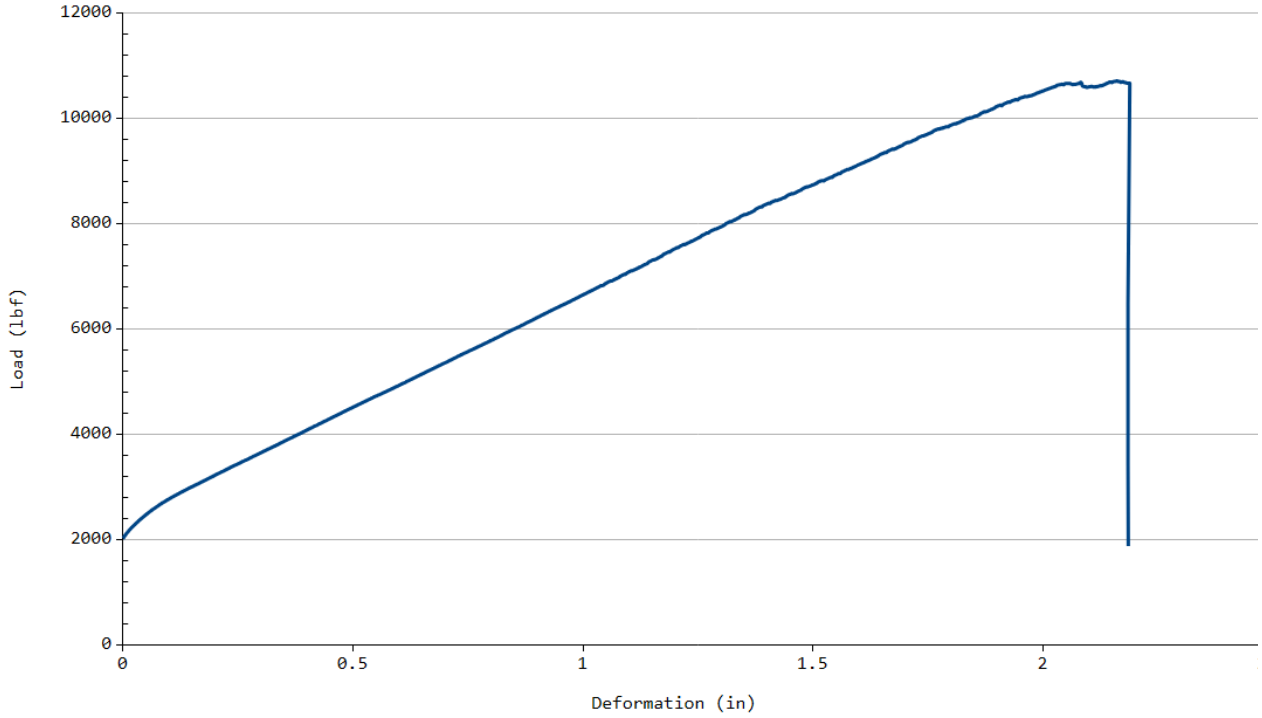


*Figure 4: Final Test Results. Test ends in strap failure at 10717lbf*

During the initial and final test parts of the strap frayed on the bottom side in the wrapped part of the strap, but the final failure point was abruptly at the top where the strap makes an 180° turn around the round bar. In Figure 5 we see the frayed wraps and broken strap.

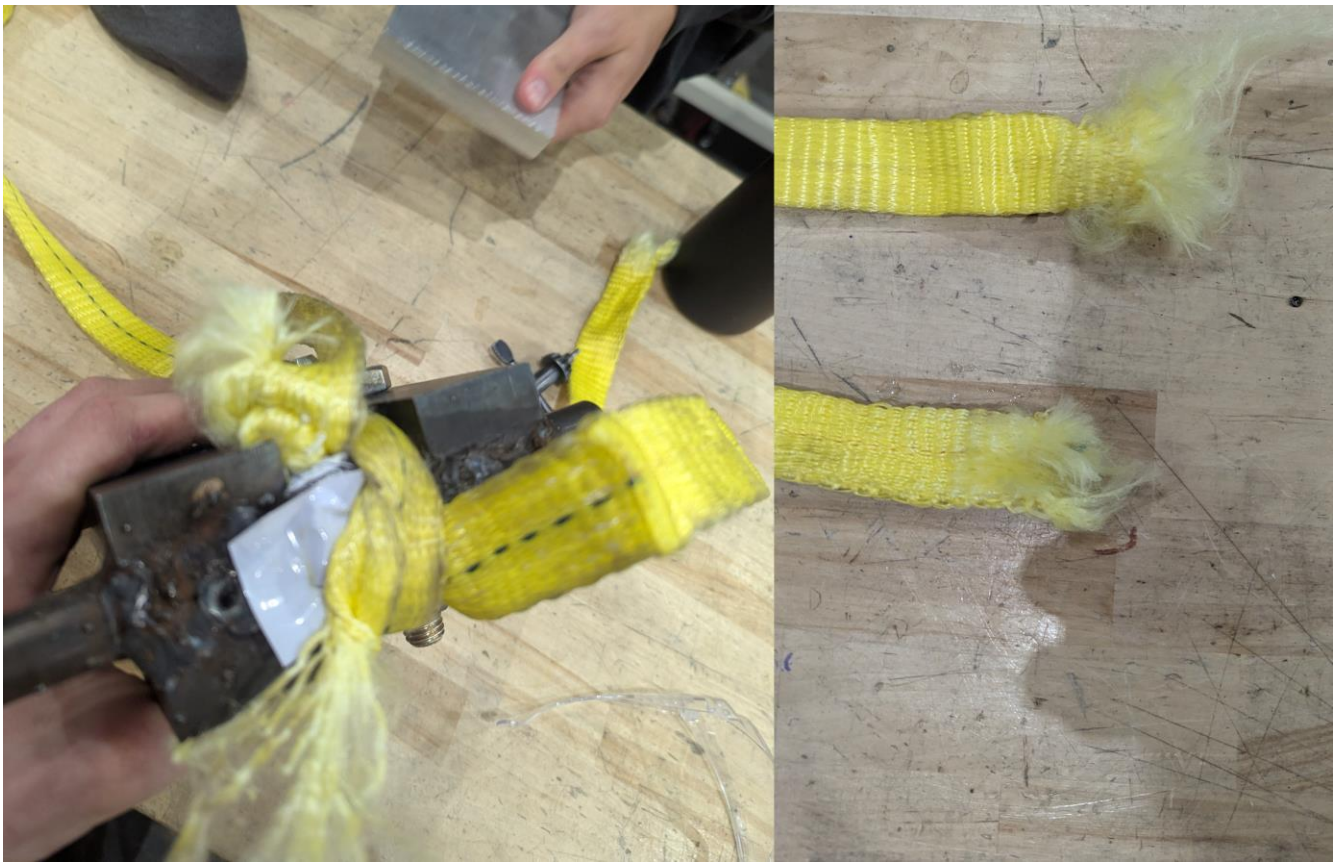

*Figure 5: Strap Failure Points. Bottom attachment point shown on the left, and top on the right.*

# 3. Test Outcome and Failure Description

The test was successful! The strap failed and the tooling did not. The strap failed exactly where it was expected to fail, at a piece of tooling. There was no observed deformation of the tooling, however deep marks from the jaws were made on the aluminum plate. This is the intent of the plate and the tooling is still usable for future tests. The tooling did slip out of the jaws, however this is not the fault of the design. Due to how the strap is wrapped on the bottom, there is lots of room for it to tighten, and this was clearly visually observed. This tightening explains the two large drops in force. The reason the tooling slipped out of the jaws was because there was a large enough slip of the strap that the force reached ~0 temporarily and the lower jaws loosened and fell under gravity away from the tooling.

# 4. Factor of Safety and Design Performance

The calculation for the experimental Factor of Safety is:

$$FoS = \frac{RealLoad}{RatedLoad} = \frac{10717lbf}{4000lbf} = 2.679$$

The rated load is based on the specification shown on the strap for double tension and is twice the rated load for single tension.  We see that the experimental factor of safety is far below the manufacture's reported value of 5.

# 5. Design Evaluation and Improvement.

Based on this test, the tooling performed exactly as intended and is a solid design. We were able to complete a full test with limited mishaps. The one mishap, the tooling coming out of the jaws was not

caused by the jaws slipping but by the strap tightening and the jaws releasing their grip. If the press were larger and the strap could be affixed to the tooling as intended the tightening issue would be all but eliminated and the tooling would not come out of the jaws. The tooling completed the test virtually unscathed and could easily test more and even larger straps.